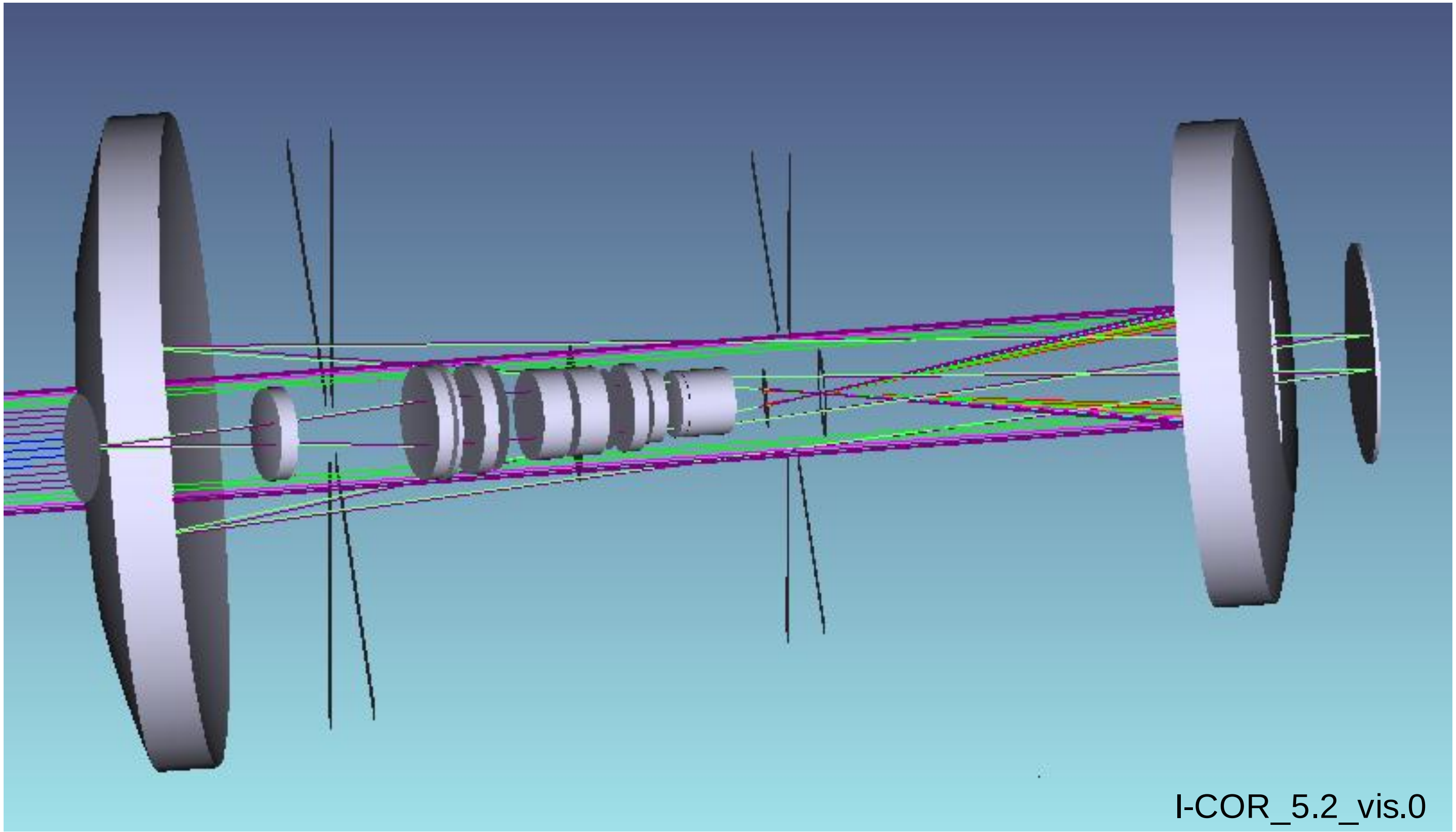
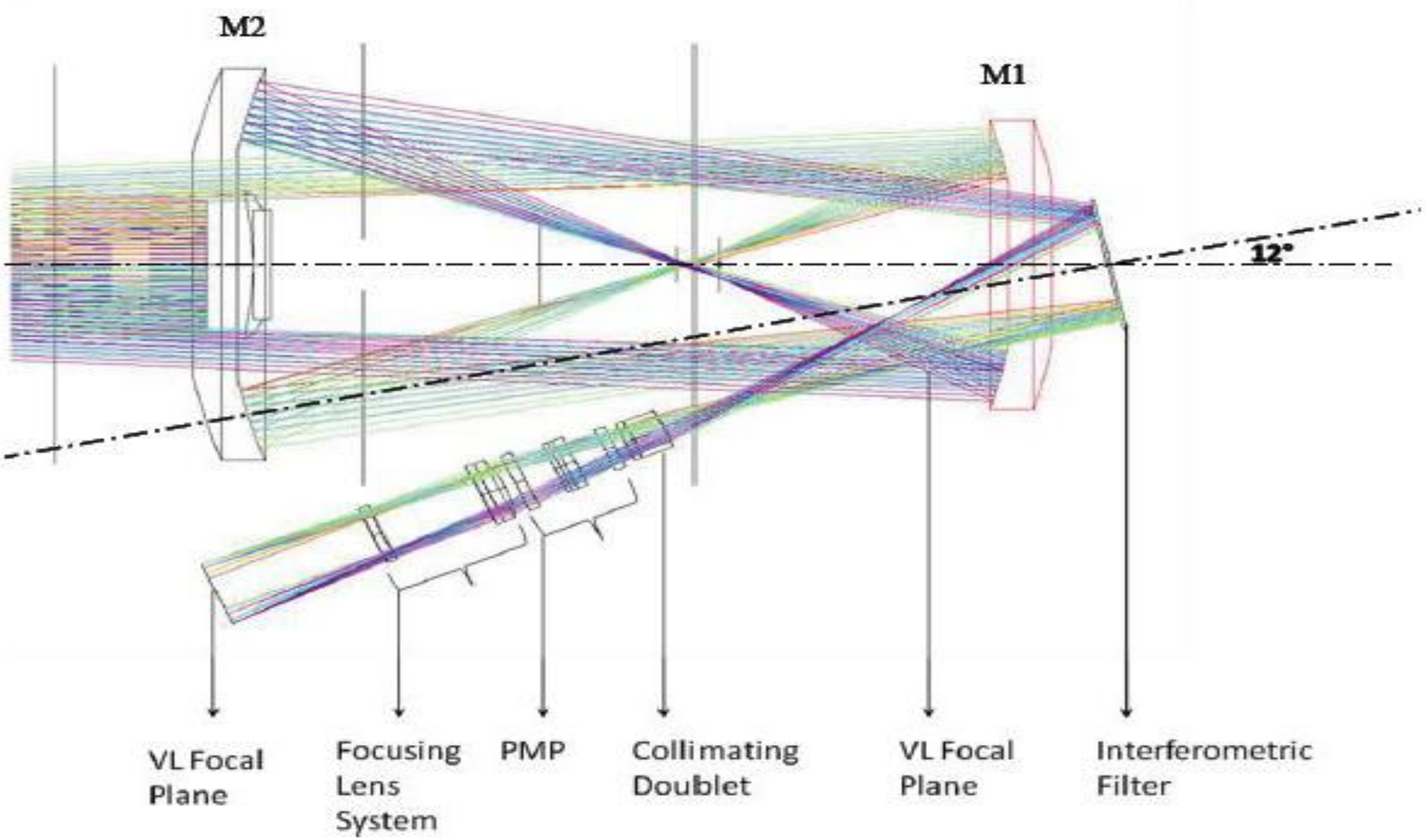
# METIS Polarimeter and I/F Filter

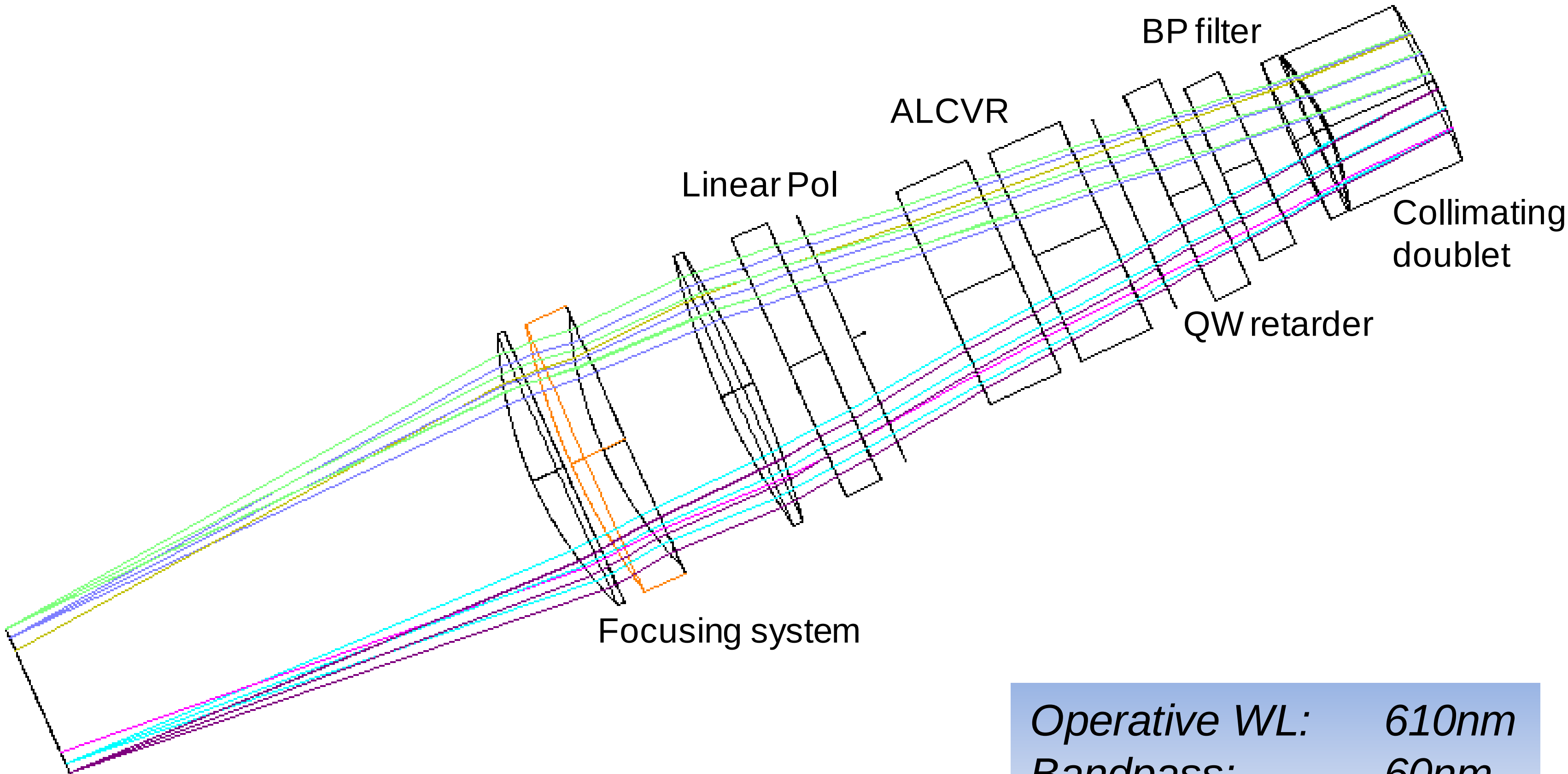



**G. Capobianco INAF- OATo**

## METIS VL PATH



# METIS Polarimeter




*Operative WL: 610nm*
*Bandpass: 60nm*
*Demagnification: 1:0.67*

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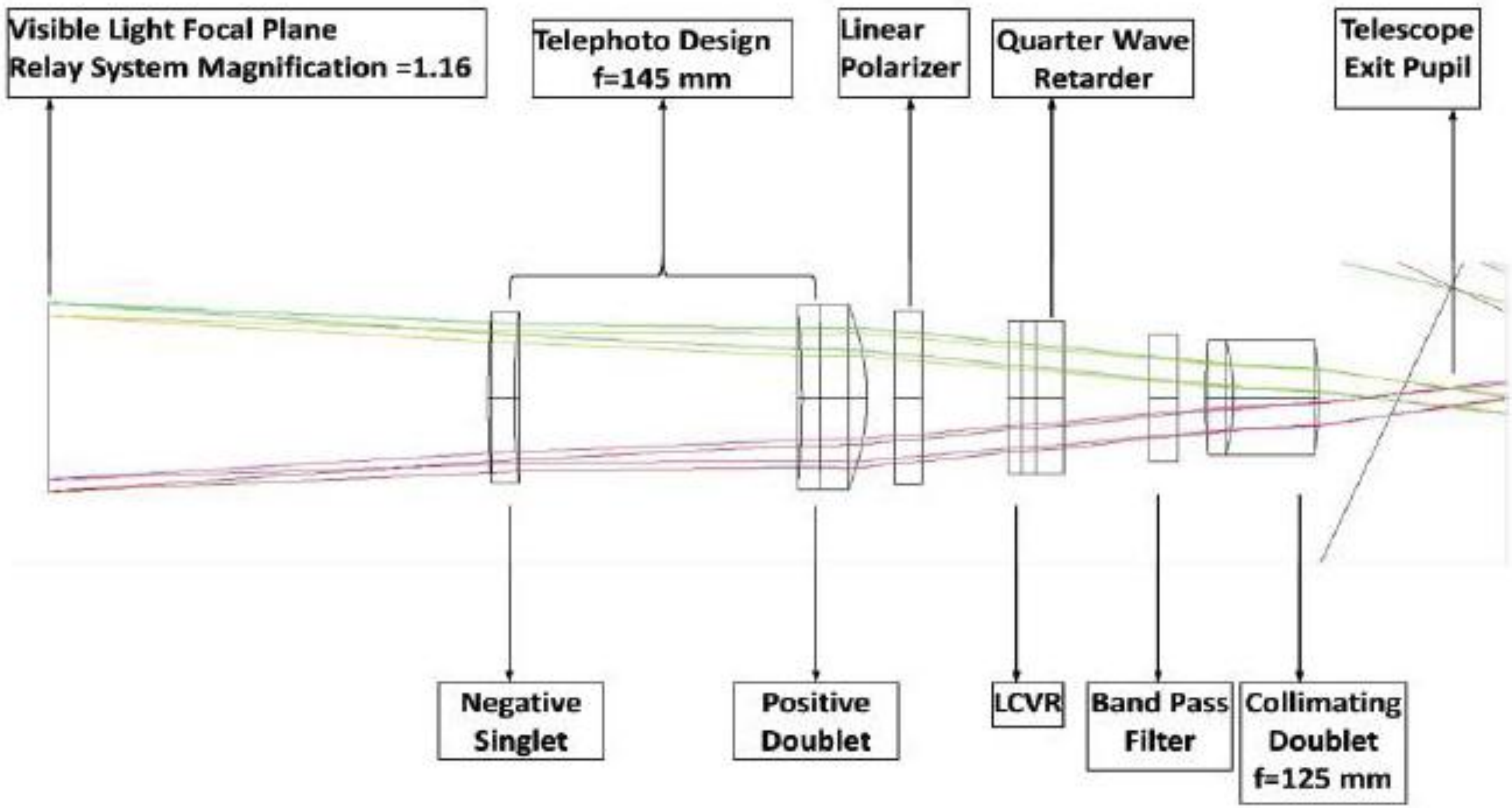
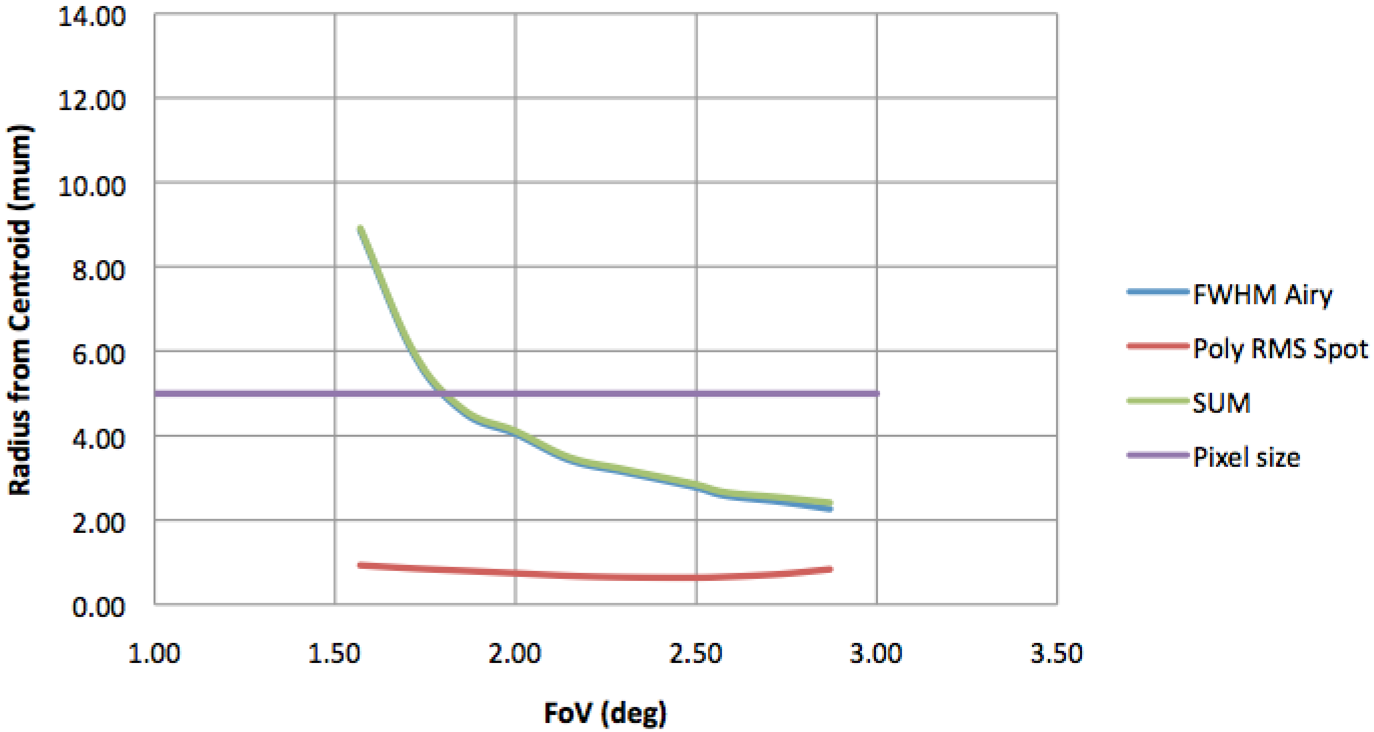
# METIS Polarimeter (Development Model)



## METIS Polarimeter / Optical Performances




The system is diffraction limited and the energy distributed in 2 pixels for almost all the FoVs. Performances can be partially recovered by an accurate calibration of the instrument response that can be deconvolved from the acquired raw image with robust maximum entropy algorithm (Crescenzio et. al., 2012)

# Measurement of polarization with METIS (1)

Stokes formalism:

$$S = (I \quad Q \quad U \quad V)^T$$

Single measured signal (single exposure at retardance $\delta_i$):

$$m_i = g\,(I + Q\cos\delta_i + U\sin\delta_i) + b$$

Linear combination of 4 images at retardance $\delta_i$:

$$\begin{pmatrix} m_0 \\ m_1 \\ m_2 \\ m_3 \end{pmatrix} = g \begin{pmatrix} 1 & \cos\delta_0 & \sin\delta_0 & 0 \\ 1 & \cos\delta_1 & \sin\delta_1 & 0 \\ 1 & \cos\delta_2 & \sin\delta_2 & 0 \\ 1 & \cos\delta_3 & \sin\delta_3 & 0 \end{pmatrix} \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$

Ideal case:

$$\begin{cases} g = \frac{1}{2} \\ \delta_0 = \frac{3\pi}{2} \\ \delta_1 = \pi \\ \delta_2 = \frac{\pi}{2} \\ \delta_3 = 0 \end{cases} \rightarrow \begin{pmatrix} m_0 \\ m_1 \\ m_2 \\ m_3 \end{pmatrix} = \frac{1}{2} \begin{pmatrix} 1 & 0 & -1 \\ 1 & -1 & 0 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{pmatrix} \begin{pmatrix} I \\ Q \\ U \end{pmatrix} \equiv M = X \cdot S$$

# Measurement of polarization with METIS (2)

Inverting the system, the polarization state of the source is derived:

$$S = X^{\dagger} \cdot M$$

Where:

$$X^{\dagger} = \frac{1}{2}\begin{pmatrix} 1 & 1 & 1 & 1 \\ 0 & -2 & 0 & 2 \\ -2 & 0 & 2 & 0 \end{pmatrix} \equiv \begin{pmatrix} X^{\dagger}_{00} & X^{\dagger}_{01} & X^{\dagger}_{02} & X^{\dagger}_{03} \\ X^{\dagger}_{10} & X^{\dagger}_{11} & X^{\dagger}_{12} & X^{\dagger}_{13} \\ X^{\dagger}_{20} & X^{\dagger}_{21} & X^{\dagger}_{22} & X^{\dagger}_{23} \end{pmatrix}$$

is the *demodulation* matrix.

**The demodulation matrix of the LC-based polarimeter is strongly dependent by the operative temperature, the angle of incident light, … knows by the lab. calibration, but unpredictable time-variations (long time) requiring the in-flight calibration.**

## Measurement of polarization with METIS (3)

The measured intensity include both, the K and F-corona:

$$B_{K+F} \equiv I$$

The fractional polarization is:

$$p = \frac{\sqrt{Q^2 + U^2}}{B_{K+F}}$$

The polarized brightness:

$$pB_{K+F} = \sqrt{Q^2 + U^2}$$

The direction angle of the linear polarization:

$$\theta = \frac{1}{2}\mathrm{atan}\left(\frac{U}{Q}\right)$$

# Measurement of polarization with METIS (4)

By the error propagation the relation between the error on a single measurement and the *pB* is:

$$\frac{\sigma_{pB}}{pB_{K+F}} \sim \frac{1}{p\sqrt{2}} \sqrt{\left(\frac{\sigma_m}{m}\right)^2 + \sigma_{X^+}^2}$$

Assuming $\sigma_{X^+} \ll {}^{\sigma_m}/_{m}$

$$\frac{\sigma_{pB}}{pB_{K+F}} \sim \frac{1}{p\sqrt{2}} \cdot \frac{\sigma_m}{m}$$

In terms of SNR: $SNR_{pB} \equiv \frac{pB}{\sigma_{pB}}$ $SNR_m \equiv \frac{m}{\sigma_m}$

$$SNR_{pB} \sim \sqrt{2} \cdot p \cdot SNR_m$$

$p \sim 0.1 \div 0.4,$

**In order to achieve a SNR of order of 10 in the pB measurement, then, depending on the K-corona polarization, *p*, a SNR in the range of ~ 100 ÷ 25 is required in the measurements of the individual images.**

# Instrumental pB (1)

The instrumental pB must be (Fineschi et. al., 2005; Capobianco et al., 2012):

$$pB_{instr} \approx 0.01$$

The contributions to the instrumental pB are coming from the I/F filter and from the polarimeter itself:

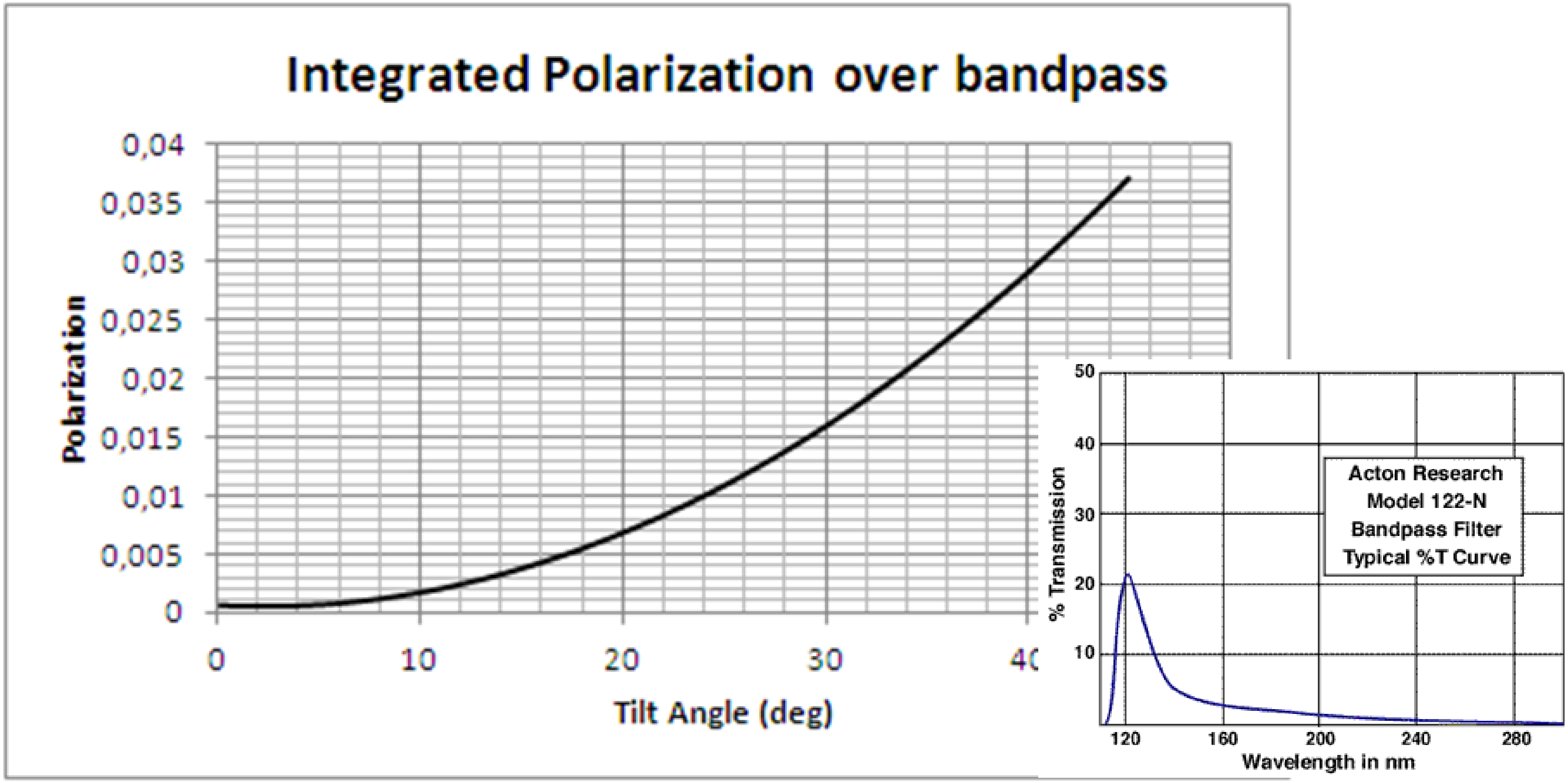
$$pB_{instr} \approx \sqrt{\Delta P_{IF}^2 + \Delta P_{Pol}^2} \approx 0.01$$

The contribution of the I/F filter has been measured in function of the tilt angle using ellipsometry tecnique:

With a tilt angle of 12 deg:

$$\Delta P_{IF} = 0.0025$$

# Instrumental pB (2)/ IF filter contribution




Measurements @ Università di Pavia

# Instrumental pB (3)/ Polarimeter contribution

The contribution of the polarimeter to the instrumental polarization is due to:

$$\Delta P_{Pol} = \sqrt{\Delta P^2_{LCVR-AoI} + \Delta P^2_{LCVR-inh} + \Delta P^2_{LCVR-chr} + \Delta P^2_{QW-inh}} \approx 0.013$$

Measured in the framework “Validation of LCVRs for the Solar Orbiter Polarization Modulation Package”:

$$\Delta P_{LCVR-AoI} < 0.00025$$

$$\Delta P_{LCVR-inh} < 0.009$$

$$\Delta P_{LCVR-chr} < 0.01$$

Extrapolated by the manufacturer specifications:

$$\Delta P_{QW-inh} < 0.001$$

$$\boxed{\Delta P_{Pol} \approx 0.009 \Rightarrow pB_{instr} \approx 0.014}$$

## Status of the development model

The procurement for the assembly of the development model is actually in progress…

THANKS FOR YOUR ATTENTION